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Extraboard Management: TriMet Case Study

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Extraboard Performance: TriMet Case Study

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EXTRABOARD PERFORMANCE: TRIMET CASE STUDY

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16. Abstract

This paper examines extraboard operations and management at TriMet, the transit provider for the Portland Oregon metropolitan area. The extraboard consists of a pool of operators who fill open work resulting from absences and other causes. The paper first examines the general performance of the extraboard in filling open work, drawing on seven years of daily operations data from three bus garages. It then presents statistical analyses focusing on open work patterns and the effects of selected work rules on operator utilization and service delivery. Lastly, suggestions are made for improving the efficiency of extraboard operations.

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Abstract

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Introduction

Scheduled service in the transit industry is organized around the assignment of vehicles and operators. The assignment of operators to scheduled service runs is typically made for a three-month period. In daily operations, assigned runs can open up as a result of absences, quits and terminations, retirements, promotions, in-service training, approved leaves, injuries, and personal days off. This open work is filled from a reserve pool of operators known as the extraboard.

The amount of open work can vary substantially from day to day, as well as seasonally. This variation poses challenges to extraboard managers. When the amount of open work is less than expected, there is a surplus of operators available at assigned report times accruing report hours (time for which they are being paid but are not in platform service). When the amount of open work is greater than expected, there is a deficit of available operators, resulting in lost service (termed "missed pull-outs"). In practice, operators are also asked to voluntarily work their days off when the supply of extraboard operators is exhausted in order to minimize the incidence of missed pull-outs.

The literature on extraboard management generally approaches the coverage of open work as a three-stage problem (*1, 2, 3*). The first (strategic) stage involves determining the optimal size of the extraboard workforce, based on expectations of the amount of open work. The time frame of this stage is usually quarterly. The second (tactical) stage involves allocation of extraboard to the transit agency's garages and subsequent assignment to days of the week, again based on expectations of open work. The time frame of this stage is also typically quarterly. In the final (operational) stage, extraboard operators and regular operators working overtime are assigned to open runs, which occurs daily.

There are a number of factors that complicate open work planning and management. For example, the absence information used in determining the size of the extraboard can be affected by work rules, operator demographics, scheduling practices, or a transit agency's unscheduled overtime work policy (*4, 5, 6, 7*). The size of the extraboard is also influenced by pay premiums and guarantees, the cost of fringe benefits, and limitations on extraboard managers' ability to combine or break up pieces of open work (*8*). These complications make it difficult for transit executives to assess the extent to which the balance between the cost of work filled by the extraboard and the benefits to customers from otherwise lost service represents the best use of agency resources.

This paper examines bus extraboard operations at TriMet, the transit provider for the Portland, Oregon metropolitan area. The analysis draws on daily extraboard data from the agency's three bus garages between 2002 and 2010. TriMet is a mid-sized transit property; on an average weekday in 2010 its bus system served 192,300 boarding riders on 79 routes with 491 peak vehicles. TriMet also provides light rail and streetcar service, which are not covered in this paper.

The remainder of the paper is organized as follows. The next section briefly reviews the literature addressing factors that influence extraboard performance. Empirical findings from analysis of TriMet's extraboard operations are then presented. These findings cover multiple levels of analysis, beginning with general performance metrics, proceeding to estimating the determinants of open work, and ending with structural estimation of various trade-offs associated with daily extraboard operations. Lastly, the findings and their implications are discussed in the concluding section.

Factors Affecting Extraboard Performance

Various work rules and benefits affect operator productivity and job performance in both the regular and extraboard service environments. Mundle et al.'s (*4*) study of three large transit agencies found that work rules and benefits collectively required one hour and 47 minutes of operator pay time to produce one hour of platform service. Their breakdown of the 47 minutes of "surplus" pay minutes covered three general categories: 1) work rules (including pay for report time, and premiums for scheduled/unscheduled overtime and holiday service), which accounted for 18 additional minutes per platform hour of service; 2) operator absences (both scheduled and unscheduled), which accounted for 10 additional minutes per platform hour; and 3) fringe benefits (including health/dental insurance, worker's compensation, and free transportation), which accounted for 19 additional minutes per platform hour.

Circumstances have grown more challenging in the years since Mundle et al.'s (*4*) study. For example, both the incidence and variability of operator absences have increased since passage of the Family and Medical leave Act (FMLA) of 1993 (*P.L. 103-3, 107 Stat. 6*). A U.S. Department of Labor report (*9*) has identified public transit as being among the industries most affected by FMLA, particularly its regulations associated with unscheduled intermittent leaves. These regulations effectively allow workers to notify their employer of such leaves up to two days *after* their occurrence. Thus, the daily process of managing open work through the extraboard has become more uncertain. Respondents to Volinsky's (*10*) transit industry survey characterized FMLA as "a nightmare," "a disaster," and "a royal pain" that is "killing them" (*p. 6*).

Beyond Mundle et al.'s (*1990*) general productivity assessment and the issues affecting operator absenteeism, there is a more specific collection of work rules that can affect the performance of the extraboard. In the present study, these rules are defined by the collective bargaining agreement currently in place at TriMet (*11*). First, the agreement includes a guarantee of eight pay hours daily for those who sign on to the extraboard, effectively limiting extraboard participation to full time operators. This makes it more difficult to piece the work of absent mini run and split shift operators into a full time run without incurring substantial report time and unscheduled overtime.

Second, extraboard operators' daily work is assigned using a revolving system known as the "red line." Under this system, extraboard operators are sorted by seniority and the first piece of work on the first day of a new service period is assigned to the most senior operator. On each subsequent day throughout the period the red line moves progressively through the extraboard roster, ensuring that no operator receives a consistently "good" or "bad" work assignment.

There are several negative consequences related to the use of the red line system. Despite its nominal fairness, the red line also produces more variable work schedules for extraboard operators. Although some operators consider this variability to be an attractive feature of extraboard work, it has been found that work schedule variation also contributes to fatigue and greater safety risk (*12*). Variable work schedules may also conflict with rules on breaks between assignments. For example, TriMet operators may turn down an assignment whose report time is less than nine hours from the time they clock out from their previous day's work. An assignment that is turned down for this

reason is known as a "pass-up." The daily progression of the red line creates pass-up situations. It should also be noted that pass-up situations occasionally arise in the regular duty operator picks.

The incidence of pass-ups can also be affected by another rule that allows operators to trade their work. The collective bargaining agreement states that trades are "critically important for extraboard operators who are unable to predict their workload, recovery time and schedules in advance" (*Article II, Section 1, Paragraph 1m*). However, an operator seeking to avoid an early morning report time, for example, may trade for that work knowing that it can be passed up when it follows a late evening assignment that they prefer.

Trades are much more common among extraboard than regular duty operators. In 2009, 31.8% of the daily work assigned to extraboard operators was traded, while only 1.2% of the work selected by regular duty operators was traded. This difference indicates that many extraboard operators use trades to obtain assignments at their preferred work times, either directly or indirectly (i.e., through pass-ups). With daily work guaranteed in the agreement, the red line may now actually serve as an impediment to matching work with operator preferences.

When a pass-up occurs, the affected operator returns to the extraboard roster for a later assignment. The passed up work will then be filled if another extraboard operator is available at the scheduled pullout time. Anticipating early morning pass-ups and unexpected absences, extraboard managers may "overstock" the supply of operators with early morning report times, frequently calling in operators to work their regular day off (RDO). Without such an overstock, lost service (missed pullouts) would otherwise result. However, when anticipated pass-ups and unexpected absences do not materialize, the surplus operators then accrue report time. Generally, given that senior management seeks to minimize lost service (and closely tracks its occurrence), extraboard managers have a strong incentive to maintain an overstock of operators on early morning report.

When extraboard operators pass up early morning reports and are shifted to later time slots, excess report time also often results later in the day. In this case, operators who are shifted supplement those who were already assigned to cover expected open work. Thus, early morning pass-ups by extraboard operators can produce excess report time both early and late in the day.

The magnitude of excess report time from pass-ups and absence uncertainties is large enough to substantially affect the productivity of the extraboard. Using daily garage data from the Massachusetts Bay Transportation Authority (MBTA), Koutsopolous and Wilson (*3*) developed an optimization tool for determining the number of extraboard operators needed by time of report. Comparing their results with MBTA's actual assignments, the authors found a 20-30% surplus of extraboard hours on report, mostly concentrated in the early morning period. TriMet's Information Technology (IT) Department has developed a similar tool that advises extraboard managers at the end of each day on the expected number of operators that will be needed on the next day, by time of report. In practice, TriMet IT staff has observed outcomes similar to those reported by Koutsopolous and Wilson (*3*). More generally, DeAnnuntis and Morris (*13*) found that most transit agencies employ no planning or optimization tools in managing their extraboards.

With respect to determining the overall number of extraboard operators needed in a given service period, there are oftentimes cost advantages in filling known open straight runs with RDO operators. However, there are two widely held concerns that limit the extent to which managers rely on RDO operators to augment the extraboard. The first concern is that such work will lead to greater subsequent absenteeism among RDO operators. Shiftan and Wilson (*6*) investigated this issue, analyzing MBTA data. Their analysis found no evidence of increased absence following voluntary overtime work. The second concern is that the additional overtime may contribute to operator fatigue and have negative safety consequences. Strathman et al. (*13*) studied this issue using TriMet data, finding no significant increase in safety incidents associated with increases in total hours worked.

Common to both absence and safety concerns is the fact that the operator's commitment to such overtime work is voluntary. In their review of literature on the relationship between safety and driver fatigue, DiMilia et al. (*15*) observe that when overtime is voluntarily chosen the safety risk increase that might otherwise materialize tends to be mitigated. Shiftan and Wilson (*6*) similarly hypothesize that when operators self-select into overtime work, they are less likely to subsequently absent themselves from work.

Empirical Analysis

Data on extraboard operations were recovered from TriMet's enterprise data warehouse for the period extending from September 1, 2002 to May 5, 2010. Daily records were created for each of TriMet's three bus garages (Center, Merlo, and Powell), resulting in 8,317 total "garage-day" observations. TriMet began archiving pass-up data on December 5, 2004. The number of garage-day observations from this date to the end of the study period totals 5,788. In the following presentation, data from the 2002-10 period are used to provide a general profile of extraboard operations, while data from 2004/5-10 are used in the statistical analysis of extraboard performance.

A summary of daily work by garage is presented in Table 1. The first two rows show average total hours of scheduled service and the hours of open work covered by the extraboard. Open work comprises nearly 16 % of each regular scheduled service. Extraboard operator platform hours also generally exceed open work hours. This surplus represents extra service (i.e., beyond what is scheduled), as well as the occasional practice of dispatching extraboard service to hold at layover points in anticipation of lost service due to breakdowns and other causes. Daily RDO operator hours are fairly small in comparison to extraboard operator hours.

Table 1 Daily Extraboard Profile by Garage, September 2002 – May 2010

	Center	Merlo	Powell	Total
Platform Hours of Scheduled Service	2427.9	1313.9	1953.1	5694.9
Platform Hours of Open Work	384.2	205.7	302.8	892.7
(% of Scheduled Service Hours)	15.8%	15.7%	15.5%	15.7%
Extraboard Operator Platform Hours	444.7	241.0	335.1	1020.8
RDO Operator Platform Hours	27.4	14.6	24.0	66.0
Extraboard Operator Report Hours	66.3	36.8	47.4	150.5
Extraboard Operator Absence Hours	52.2	31.3	47.9	131.4
(% of Extraboard Operator Platform Hours)	26.6%	28.3%	28.4%	27.6%
Total Extraboard Pay Hours	590.6	323.7	454.4	1368.7
(% of Scheduled Service Hours)	24.3%	24.6%	23.3%	24.0%
Missed Pullout Hours	0.6	0.8	0.6	2.0
(% of Scheduled Service Hours)	.02%	.06%	.03%	.04%
Extraboard Efficiency	1.54	1.57	1.50	1.54

Extraboard operator report hours represent pay hours when an operator is on duty not in platform service. Such hours can accrue between operators' assigned report and pull-out times, during periods between separate pieces of assigned work, or during times

following assigned work when they are held to fill unanticipated openings that may arise. Report hours are thus a direct consequence of efficiency losses associated with open work uncertainty and the indivisibility of open work pieces (particularly those providing peak service). Absences among extraboard operators are another source of time loss from platform service. The effective platform service time losses from extraboard absences and report time are of roughly similar magnitude, and jointly represent about 28% of the platform hours filled by extraboard operators.

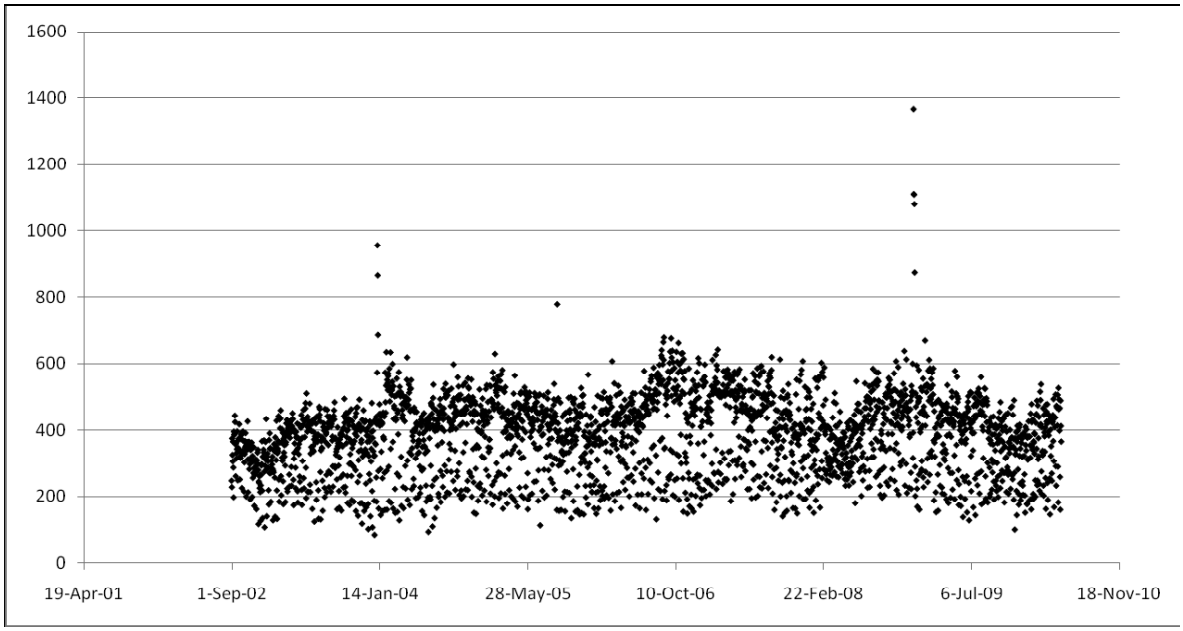
Collectively, the pay hours for extraboard and RDO operators (including report and extraboard absence hours) expended in covering open work amount to 24% of regular scheduled service hours. A small amount of unfilled open work remains when the extraboard runs short of available operators. Such service lost to missed pull-outs averages less than an hour per garage per day, or about one trip per garage.

The final row in Table 1 presents a composite measure of extraboard efficiency, defined as the ratio of total extraboard pay hours to the hours of open work (less missed pull-out hours). Thus, for example, Center garage extraboard operations require 1.54 pay hours to cover each hour of open work, while Merlo and Powell require 1.57 and 1.50 hours respectively. These small differences may reflect garage-related distinctions in the runs that must be covered by the extraboard (e.g., more peak trippers needing coverage at Center and Merlo), or they may reflect differences in the ability of station agents at the garages to piece together open work and effectively match it to operator report times.

While the information in Table 1 provides a general perspective of the scale of extraboard operations, it does not reflect the day-to-day variability in the open work that must be covered. This variability is illustrated in Figure 1, which plots Center garage's daily open work over the 2002-10 period.

Several observations can be made about the open work plot in Figure 1. First, the coefficient of variation (a standardized measure of variability) for this plot is .31, indicating that the standard deviation of daily open work is equal to 31% of the period-wide average daily amount. Second, the plot appears to be denser toward the upper end of the range of values, indicating that the frequency distribution of open work tends toward log normal rather than normal. Third, a general trend is evident, with open work increasing from September 2002 to about September 2006, and subsequently decreasing for the remainder of the study period. Lastly, a small number of large value points can be seen for dates associated with severe weather events. For example, a freezing rain event in early January 2004 disrupted scheduled service (and the extraboard) on three consecutive days, while heavy snow in late December 2008 had similar consequences on four consecutive days.

Figure 1 Center Garage Daily Open Work Hours, September 2002 – May 2010



Determining the extent to which open work variability (as illustrated in Figure 1) can be systematically predicted is an important part of the extraboard workforce planning process, otherwise known as "sizing the extraboard." This exercise partly depends on determining whether distinct absence patterns exist among regular duty operators. As Strathman et al. (*7*) have shown, operator absence frequencies vary in fairly predictable ways by day of the week, month, year, and garage. Apart from absences, open work is directly affected by any work that remains unassigned in quarterly picks and by work that opens up during a quarter due to retirements, quits, and terminations. Lastly, open work is affected by work rules, such as those resulting in pass-ups by regular operators.

Table 2 shows the results of a regression of daily open work hours on scale, temporal, garage, and work rule factors for the 2004/5-10 period. The results indicate that the amount of open work increases at a decreasing rate with the growth of both scheduled service and unsigned runs. Each pass-up by a regular duty operator results in his work being sent to the extraboard, increasing the estimated total by about 3.4%, or 10.3 hours. Controlling for scale differences among garages, the amount of daily open work is estimated to be about 9.3% (27.9 hours) lower at Merlo and 2.0% (5.9 hours) lower at Powell than at Central.

Turning to temporal factors, fewer daily open work hours were estimated in the years subsequent to 2004/5, with greatest reductions (relative to 2005) occurring in 2009 (-4.6%, or 13.9 hours per day per garage) and 2010 (-4.0%, or 12.1 hours per day per garage). Although estimated open work hours in 2008 were less than 2004/5, they were 1.2% (or 3.6 hours per day per garage) higher than 2007.

Seasonality in open work hours is evident in the parameter estimates for the monthly dummy variables. Estimated open work hours are lowest during autumn months, with a minimum occurring in November. Relative to November, the estimated differential in daily open work hours per garage peaks during the months of June (12.8%, or 38.5 hours per day higher than November), July (14.1%, or 42.6 hours), and August

(16.9%, or 51.0 hours). A somewhat smaller peak is also estimated for February (9.3%, or 28.0 hours per day higher than November), during the height of the cold and flu season. Regarding the summer peak, it should be noted that most vacation relief service is covered through regular duty operator assignments rather than the extraboard. However, regular duty operators may concentrate their floating holiday and personal days off during this time, which must be covered by the extraboard.

Open work variability is also evident over the course of the week, with a minimum estimated to occur on Sundays. At the other end, the daily differential relative to Sunday is estimated to be greatest on Fridays (14.8%, or 44.7 hours per garage) and Saturdays (18.9%, or 56.9 hours per garage). Lastly daily open work per garage is estimated to be 6.9% (or 20.7 hours) lower on holidays, when operators are paid overtime.

Table 2 **Open Work Model Coefficients**
(Dependent Variable = ln Open Work Hours)

Variable	Coefficient	t-value
Constant	4.2959	91.09
Scheduled Service Hours	.0066	16.52
Scheduled Service Hours^2	-1.12e-07	-13.19
Open Run Hours	.0039	28.67
Open Run Hours^2	-4.72e-06	-8.05
Regular Duty Operator Pass-ups	.0341	16.27
Center Garage	--	--
Merlo Garage	-.0926	-4.00
Powell Garage	-.0195	-2.12
Year 2004/5	--	--
Year 2006	-.0123	-1.66
Year 2007	-.0275	-3.59
Year 2008	-.0156	-2.08
Year 2009	-.0461	-6.27
Year 2010	-.0400	-3.67
January	--	--
February	.0928	8.87
March	.0540	5.26
April	.0865	8.35
May	.0789	7.34
June	.0978	8.91
July	.1122	10.29
August	.1401	12.91
September	.0451	4.11
October	.0410	3.78
November	-.0290	-2.63
December	.0226	2.09
Sunday	--	--
Monday	.0455	1.53
Tuesday	.0066	0.03
Wednesday	.0456	1.52
Thursday	.0427	1.42
Friday	.1483	4.95
Saturday	.1889	17.98
Holiday	-.0687	-2.53
R^2	.84	
Sample Size	5788	

At its most disaggregate level, the extraboard can be represented in terms of the daily allocation of operators' time. In filling open work, the extraboard manager seeks to maximize the platform time of available extraboard operators while minimizing their time on report. He also seeks to minimize lost service time from missed pull-outs by ensuring adequate availability of extraboard operators, supplemented when necessary by RDO operators. Thus, the manager's responsibility encompasses four basic time components: 1) the platform time of extraboard operators; 2) the platform time of RDO operators; 3) the report time during which extraboard and RDO operators must be paid while they wait to fill an extraboard service assignment; and 4) the lost service time associated with missed pull-outs.

Empirical analysis of the extraboard time management problem can be generally represented by the following set of equations:

EO Hours = f(Open Work Hours, RDO Hours, EO Absence Hours)

RDO Hours = f(Open Work Hours, EO Hours, EO Absence Hours, EO Pass-ups)

Report Hours = f(Open Work Hours, EO Hours, RDO Hours, EO Pass-ups)

Missout Hours = f(Open Work Hours, EO Hours, RDO Hours EO Pass-ups, Report Hours),

where

EO Hours = daily extraboard operator platform hours per garage;

RDO Hours = daily extraboard platform hours of RDO operators per garage;

Report Hours = daily paid report time of operators working the extraboard per garage;

Missout Hours = daily of lost service from missed pull-outs per garage.

Open Work Hours = daily hours of open work per garage;

EO Absence Hours = daily absence hours of extraboard operators per garage;

EO Pass-ups = daily pass-ups of extraboard-assigned work per garage.

The open work hours variable is specified in each of the equations to capture scale effects associated with the platform service hours covered by extraboard and RDO operators, along with the hours spent on report and the hours of lost service from missed pull-outs. Selected variables are also specified on both sides of the equation system to address trade-offs and simultaneity effects. This is the case with extraboard and RDO operator platform hours, where (for a given amount of open work) an increase in work performed by one operator type is expected to offset the amount of work that is performed by the other. Report hours are also specified on both sides of the equations in the system. In one respect, report hours are a consequence of the amount and

composition of open work that is filled. Alternatively, report hours can also serve as a buffer against lost service from missed pull-outs by assuring operator availability.

Pass-ups by regular duty operators have already been examined in terms of their effects on the creation of open work. For extraboard operators, pass-ups can be expected to have two consequences. First, they may result in additional report hours when the affected operator must be reassigned to a later piece of open work. Second, they result in an increase in missed pull-out hours when another operators is not available to cover the work that has been turned down. Lastly, absence hours among extraboard operators can be expected to have three consequences: 1) they reduce the capacity of the extraboard to cover open work; 2) they trigger the need for additional RDO operators; and 3) they increase the likelihood of additional lost service from missed pull-outs.

There are several issues related to estimating the set of equations. First, there is no *a prioi* knowledge of their appropriate functional form. This is addressed by testing Box-Tidwell exponential transformations of the variables (*16*), where the limiting alternatives are log and linear transformations. Second, in the case of log transformations, zero values are undefined. Thus, following Dixon et al. (*17*), where zero values exist (e.g., missed pullout hours, pass-ups), they are replaced by the corresponding smallest observed values in the sample. Third, when error covariances among the equations are nonzero, estimation efficiency is improved by estimating the equations as a seemingly unrelated system (*18*).

Iterative Zellner estimates of the coefficients of the four-equation system are presented in Table 3. Testing of Box-Tidwell transformations resulted in a log linear specification of all dependent variables, while the outcome was mixed between linear and log linear specification of the independent variables depending on the equation. The following discussion interprets the coefficient estimates in terms of the effect of a unit change of a given variable at its nominal mean value.

Beginning with the open work variable, the coefficients indicate that a one hour increase is estimated to result in a 1.5 hour increase in extraboard operator platform time, a 1.05 hour increase in RDO operator platform time, a 1.5 minute increase in extraboard operator report time, and a 42 second increase in missed pull-out time. The relatively smaller marginal effect of open work increases on RDO operators' platform time likely reflects the practice of pre-assigning them to specific straight runs. Thus, as expected, they deliver about an hour of service for each hour of open work. The much larger platform time effect estimated for extraboard operators likely corresponds to the practice (discussed earlier in reference to Table 1) of adding service beyond actual open work to avoid excessive report time.

For RDO operators, a one hour increase in their assigned work is estimated to be associated with a 1.8 hour reduction in the assigned work of extraboard operators. It is also estimated to result in a 1.5 minute reduction in report time and a 42 second reduction in time loss from missed pull-outs. In contrast, a one hour increase in work performed by extraboard operators is estimate to be associated with a 50 minute reduction in work performed by RDO operators, a 5.5 minute reduction in report time, and a negligible reduction time lost from missed pull-outs.

The results related to extraboard operator absences reveal an unexpected outcome. Here, a one hour increase in extraboard absences is estimated to result in a 36 minute increase in the work that they collectively perform. One possible interpretation of this

finding is that absence patterns among extraboard operators are similar to the patterns of operators assigned to regular scheduled service. Thus the amount of open work, and work assigned to extraboard operators, would grow with increases in absences of both groups. However, this would also indicate that there would likely be a surplus of available extraboard operators on the days when absences among regular duty operators (and corresponding open work) are low. Beyond the effects on worked performed, a one hour increase in extraboard absence hours is estimated to result in a 5.4 minute increase in work performed by RDO operators and a 29 second increase in time lost from missed pull-outs.

When extraboard operators pass up their assigned work, this results in an estimated 2.6 hour increase in work performed by RDO operators. Extraboard operator pass-ups are also estimated to result in a 2.0 hour increase in report time and a 1.1 minute increase in time lost from missed pull-outs. Lastly, a one hour increase in report time hours is estimated to result in a 1.45 minute decrease in time lost to missed pull-outs.

The latter result is consistent with the common extraboard practice of maintaining a report time buffer to respond to unexpected instances of open work. In this context, the optimal buffer time is an amount where the marginal cost of report is equal to the marginal benefit of passenger waiting time saved per avoided missed trip. TriMet's system average trip time is about one hour, its average boardings per trip is 33, and its average headway is 20 minutes. Passenger waiting time saved from an averted missed trip would thus be thus 660 minutes (33 x 20). Pratt et al. (*19*) report a value of waiting time equal to the passenger's wage rate, while the average occupational wage for the Portland area is reported to be $22.00 per hour (*20*). Thus, the estimated passenger wait time benefit from an averted missed trip would be $242 (660 x 22/60). In contrast, the regression results indicate that 41.38 hours of additional report time would be needed to reduce missed pull-outs by one trip (60 minutes / 1.45 minutes). At an average hourly compensation rate (wage plus fringe benefits) of $42.00, the associated cost of a trip-saving report buffer would be $1,738 (42 x 41.38). Thus the marginal cost of the report time buffer exceeds the marginal benefit by more than a factor of seven. This indicates that there has been an over-commitment of report hours by the extraboard with respect to minimizing missed pull-outs. Thus, while reducing report hours would lead to an increase in missed pull-outs, the resulting savings in extraboard costs would exceed the increases in passenger wait costs.

Table 3 **Extraboard Time Allocation Model Coefficients***
(Asymptotic t-values in parentheses)

Variable	Extraboard Service	RDO Service	Report Hours	Missed Pullout Hrs
Constant	4.7578 (721.10)	-6.1350 (-10.14)	3.8900 (28.81)	0.3287 (1.49)
Open Work Hours	.0034 (144.46)	--	--	.0146 (22.59)
ln Open Work Hours	--	12.9488 (63.39)	-.1463 (-5.16)	--
Regular Duty Operator Overtime Hours	-.0054 (-52.45)	--	--	-.0178 (-13.34)
ln Regular Duty Operator Overtime Hours	--	--	-.0314 (-19.08)	--
Extraboard Operator Absence Hours	.0017 (14.56)	.0036 (1.91)	--	.0100 (7.70)
Extraboard Operator Platform Hours	--	--	.0018 (21.60)	--
ln Extraboard Operator Platform Hours	--	-11.5486 (-58.56)	--	-.0073 (-13.05)
Extraboard Operator Pass-ups	--	.1073 (6.86)	.0385 (17.15)	--
ln Extraboard Operator Pass-ups	--	--	--	.1134 (5.58)
ln Extraboard Operator Report Hours	--	--	--	-1.5482 (-24.08)
Asymptotic R^2	.84	.34	.39	.22
Sample Size	5788	5788	5788	5788

* The dependent variables for the four equations are as follows:

Extraboard Service Equation: ln Extraboard Operator Platform Hours
RDO Service Equation: ln Regular Duty Operator Overtime Hours
Report Hours Equation: ln Extraboard Operator Report Hours
Missed Pullout Hrs Equation: ln Missed Pullout Hours

It should be noted that, as defined above, the customer wait time benefit represents the direct consequence of avoiding a missed trip. Other potentially relevant customer benefits are not captured in the trade-off examined above. For example, if a transfer is subsequently missed due to lost service, additional wait time will accrue. Also, a penalty (sometimes monetary) is incurred when customers are delayed relative to their planned arrival times (*21*). Lastly, missed pull-outs degrade service reliability, an important attribute that in the attraction and retention of customers (*22, 23*). Fully accounting for these factors would increase total customer benefits of avoiding a missed trip and thus narrow the wait benefit/report cost difference obtained above. While these consequences cannot be documented in the present study, they should be considered in future work.

Conclusions

This report has examined the performance of bus extraboard operations at TriMet. At the system level, the extraboard must be sufficiently staffed to cover open work that, on average, amounts to 16% of TriMet's scheduled service. In this study, statistical analysis of open work patterns found seasonal variability that generally corresponds to the variability of regular operator absences found in previous work (*7*). Seasonality can be fairly readily accounted for in extraboard work force planning. Open work patterns were also found to vary systematically across days of the week, which can be tactically managed. Statistical analysis of the extraboard at the operational level identified several work and assignment practices that diminish resource efficiency, including assigned work pass-ups and a tendency toward maintaining excess report time. These findings are discussed further below. It should be recognized that the following conclusions reflect operating conditions and work rules that exist in one case study property. Although these conditions and rules are likely to be fairly common in the transit industry, there is presently little systematic knowledge of specific work provisions contained in collective bargaining agreements across the industry.

The overall size of the extraboard represents a substantial commitment of agency resources to maintaining scheduled service. It thus follows that the greatest opportunity for improving the general efficiency of the extraboard would be through achieving gains in the attendance rate of regular duty operators. Considerable attention was given to this issue in the 1980s and 1990s in response to a trend increase in absenteeism that occurred during that time (*24, 25, 26, 27*). Then, researchers cautiously encouraged the use of economic incentives (through gain sharing programs) to improve attendance. Given that a one-hour improvement in regular operator attendance in the present study would release an additional 1.4 extraboard operator hours, there would be an opportunity for substantial monetary gains by both operators and TriMet under a gain sharing arrangement.

While the seasonal variations in open work can be reasonably managed, varying daily patterns are more problematic. Although gain sharing could be structured to address the days where open work tends to be greatest, the problem could also be partially mitigated by changes in practice. For example, the practice of granting personal days off on Fridays, Saturdays, or Mondays (which are typically lower attendance days among regular duty operators) could be discouraged, as could the practice of scheduling in-service training for operators on Fridays or Mondays.

Among the factors reducing extraboard efficiency is the process of piecing together open work associated with peak period tripper service and splits. This process would become more efficient if part time operators were allowed to sign onto the extraboard. This option has been traditionally resisted in part due to the perception that part time status is an initial, transitional step of recently hired operators on their way to full time status. While this perception is valid for most part time operators, it does not hold universally. About 20% of TriMet's part time operators pass on the opportunity to move to full time status, signaling that this represents their preferred level of employment. Thus they are not always junior to full time operators in terms of seniority, and allowing their entry would not necessarily undermine the traditional privilege of extraboard sign-up being reserved for full time operators.

Operators may pass up a piece of assigned work when its report time is less than nine hours from the previous day's sign out. Pass-ups by regular duty operators were found to add to the volume of open work, while pass-ups by extraboard operators contributed to increases in both report time and time lost from missed pull-outs. Regular operator pass-ups occur as a consequence of the work selection process or as a result of trading their assigned work with another operator. Thus, the quarterly work selection process should discourage operators from piecing runs together that include pass-up situations. Trades into pass-up situations should also be discouraged.

Pass-ups among extraboard operators can arise as a consequence of the daily progression of the red line or as a result of trades. Use of the red line at TriMet can be traced to a time when pay was not guaranteed. The red line thus ensured a fair distribution of the open work that became available. Presently, however, extraboard operators are guaranteed full pay. A second function of the red line is to ensure that no operator is "locked into" an undesirable report time or piece of work throughout the sign-up. Thus, it appears that the red line has outlived its "fair compensation" rationale, and it is worth assessing how strongly extraboard operators support its use in "mixing up" work assignments. As with regular duty operators, trades into pass-up situations should be discouraged within the extraboard.

Analysis has found that report time provides a buffer against missed pullouts. In the present case, however, the costs associated with dedicating report time toward this objective are considerably greater than the direct benefits that passengers obtain through reduced wait times. This leads to the conclusion that there is excess report time in extraboard operations. Reducing report time would yield a net benefit to both TriMet and its customers if the resulting savings were reinvested in additional scheduled service. However, such action would also marginally increase time lost to missed pull-outs, a key performance outcome that is closely watched by senior management. In their efforts to drive missed pull-outs to very low levels, operations managers have generally lacked corresponding information on the cost of "missed pull-out insurance" represented in excess report time. Similarly, while extraboard managers are held accountable for missed pull-outs, they are less likely to be called to account for a few additional report hours. With access to the relevant cost and benefit information, both operations and extraboard managers will be in a better position to identify a missed pull-out target that represents the most efficient use of agency and customer resources.

A final point relates to the process through which changes in practice are implemented. In this case, elimination of the red line and limiting work trading activity are changes that can only be achieved at the bargaining table through contract negotiations. Transit executives often lack information on the cost impacts of such work rules and, as a consequence, tend to focus bargaining attention elsewhere. However, as this paper shows in the context of extraboard operations, selected work rules can have non-trivial performance and cost consequences, and deserve more careful examination.

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